N86-30198

ROTOR INSTABILITY DUE TO LOOSE ROTATING PART

Agnes Muszynska
Bently Rotor Dynamics Research Corporation
Minden, Nevada 89423

Loosening of a rotating part from its fixed position on the shaft or a part of the stator which comes loose and begins to turn with the rotor represents very frequent machinery malfunction. The loose part becomes involved in rotative motion mostly due to dry or fluid friction, and thus its motion is very erratic. The loose part can also move axially along the shaft. Detachment of the rotating part causes changes in the rotor balance state. Most often this results in higher unbalance. During steady-state operation the effect of a loose rotating part can manifest itself through beat vibration. It can be diagnosed by observing periodic changes of amplitude and phase of the synchronous response. During start-up (or shutdown) a loose rotating part carrying some amount of unbalance may manifest its dynamic action in the form of subsynchronous vibrations, very similar to those of other instabilities.

OBJECTIVE

The objective of this demonstration is to observe the effect of a loose rotating part (fixed, however, in the axial direction) under both steady-state (rotor constant speed) and transient (rotor start-up or shutdown) operation. The dynamic response depends very much on the amount of damping in the system: lubrication of the loose part/shaft surfaces and addition/elimination of aerodynamic drag blades, mounted on the loose disk, significantly change the rotor response.

ROTOR SYSTEM

The system consists of a shaft carrying a fixed disk and another "loose" disk mounted on the shaft with a rolling element bearing (Fig. 1). Both disks can be forced to rotate together when they are mechanically attached, or the second ("loose") disk can rotate freely on the shaft, when the attachment is cut off. The "loose" disk can be allowed to start its free rotation at any chosen rotor speed. Four, three, or two air drag blades of various sizes can be mounted on the "loose" disk to introduce an external resistance torque.

INSTRUMENTATION

Two eddy current noncontacting proximity probes mounted in X-Y configuration next to the loose disk allow monitoring of the rotor vertical and horizontal displacements. A Keyphasor® probe gives phase and rotative speed measurements. Oscilloscope serves for continuous observation of the vibration pattern. Spectrum Analyzer yields amplitude/frequency relationship for the vibration signals.

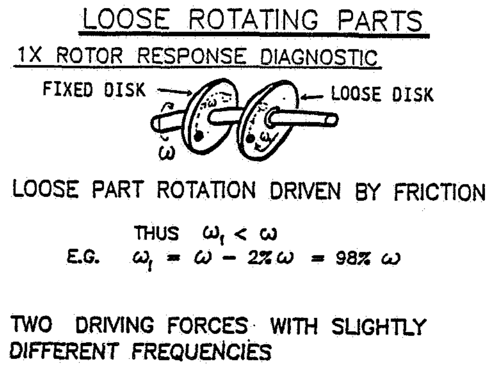

Figure 1. - Rotor with loose rotating part.

TEST RESULTS

During steady-state operation, a loose rotating part causes the generation of beat vibrations with close frequencies. This can best be observed by changes of amplitude and phase of the synchronous response. The change of phase is easily observed by noting the angular position of the Keyphasor mark superimposed on the time base trace (Fig. 2).

The effects of the amplitude and phase changes are also apparent on the oscilloscope orbit presentation (Fig. 3).

Results for transient conditions are given in the form of cascade spectra for several cases of start-up and shutdown of the rotor with the loose rotating part (Figs. 4 through 11).

Note that the resulting subsynchronous vibrations have a form very similar to the results yielded by other instabilities. Therefore, loose rotating parts can be erroneously identified as whirl, whip, or rub instability.

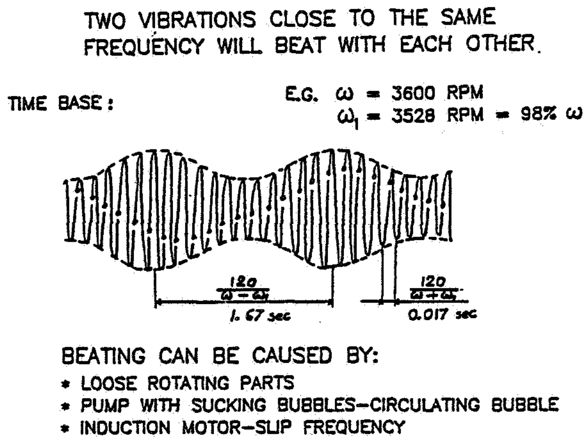

Figure 2. - Beat vibrations at steady-state machine operation due to disconnected unbalance, vibrating with frequency slightly lower than rotative speed, of loose rotating part.

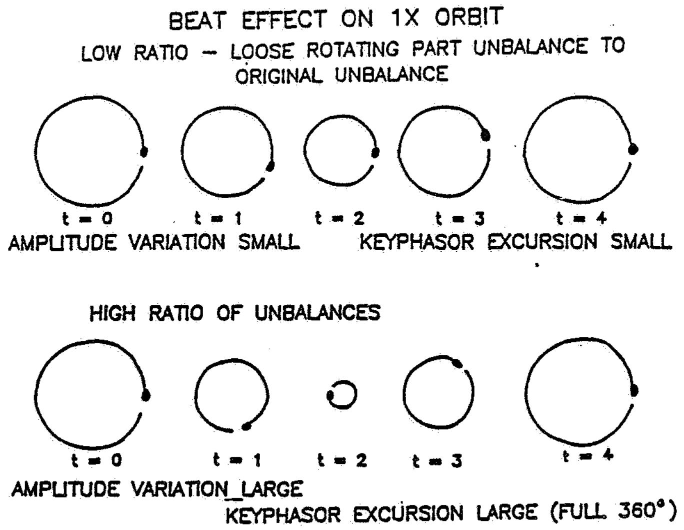

Figure 3. - Beat effect on synchronous orbit: amplitude and keyphasor mark position variations (t = time).

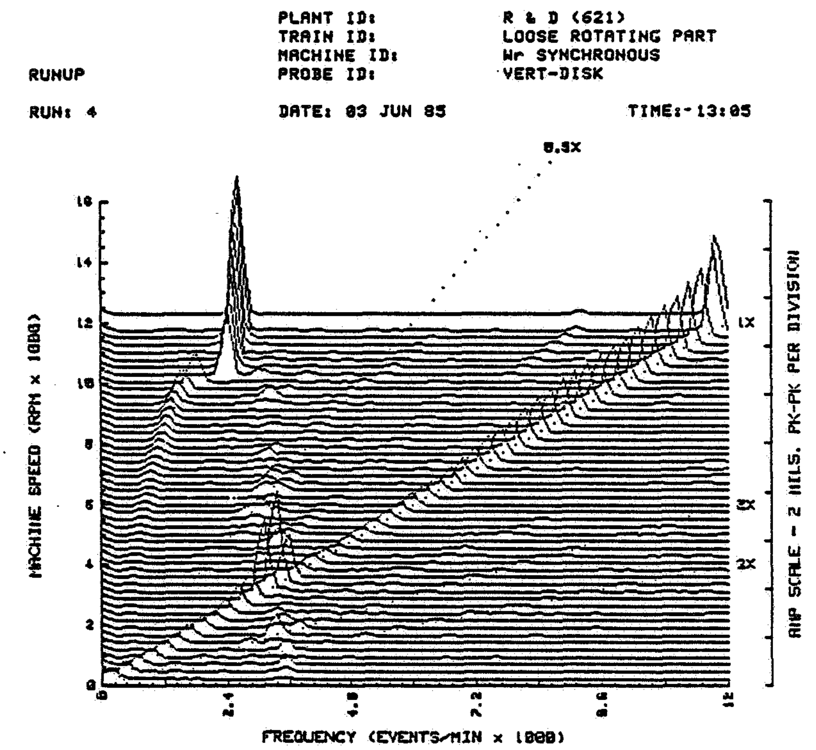

Figure 4. - Cascade spectrum for four-blade, loose-disk rotor startup response. Loose part generated subsynchronous vibrations, especially pronounced at high rotative speeds. Frequency of vibrations slightly lower than rotor first balance resonance frequency.

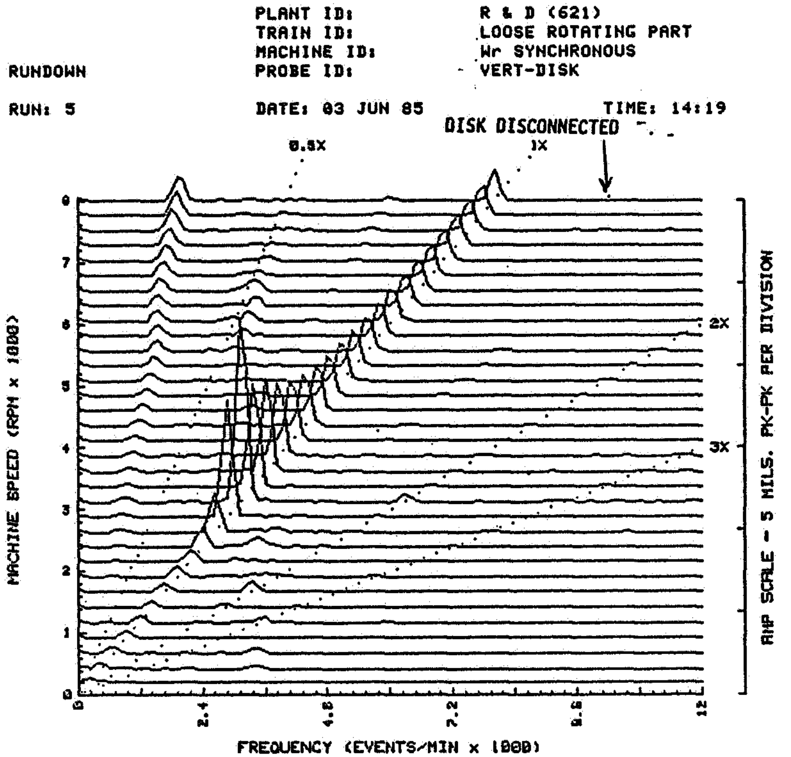

Figure 5. - Cascade spectrum of rotor response during shutdown. Four-blade disk disconnected from main rotor at rotative speed (8000 rpm). Frequency of subsynchronous vibrations caused by loose disk, ~1/4X.

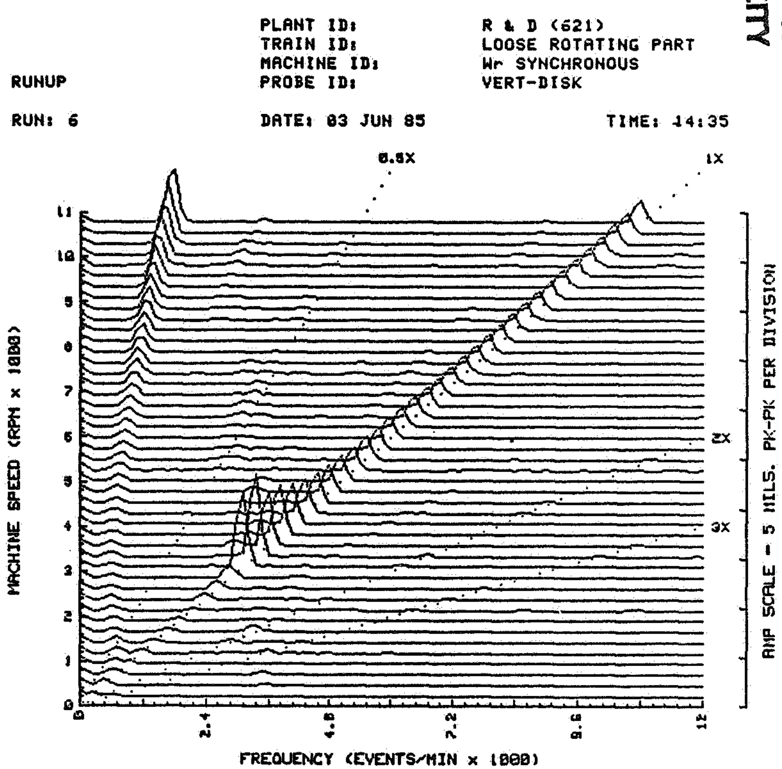

Figure 6. - Cascade spectrum for three-blade loose-disk rotor startup response. Frequency of subsynchronous vibrations caused by loose disk, ~1/6X.

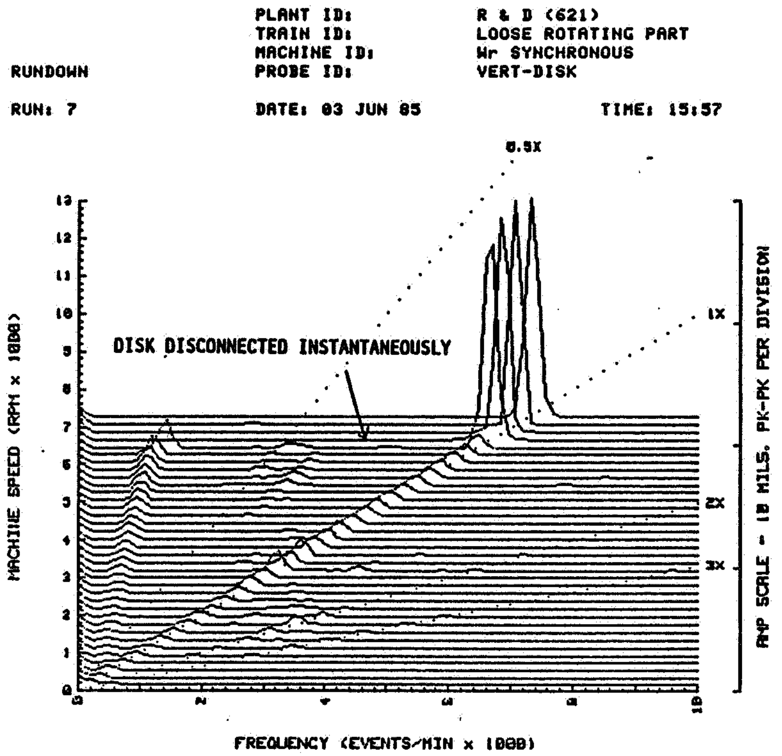

Figure 7. - Cascade spectrum of rotor response during shutdown. Three-blade disk disconnected from main rotor at rotative speed (6500 rpm). Frequency of subsynchronous vibrations caused by loose disk, ~1/6X.

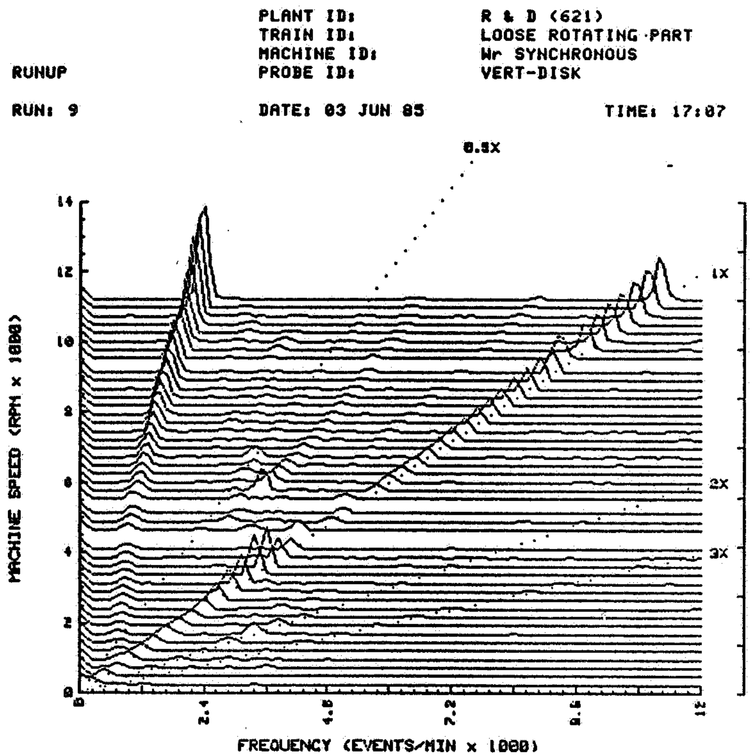

Figure 8. - Cascade spectrum for two-blade, loose disk rotor startup response. Frequency of subsynchronous vibrations caused by loose part, ~1/5X; frequency of additional subsynchronous vibrations, ~3/5X; amplitude becomes significantly high when rotative speed reaches double first balance resonance.

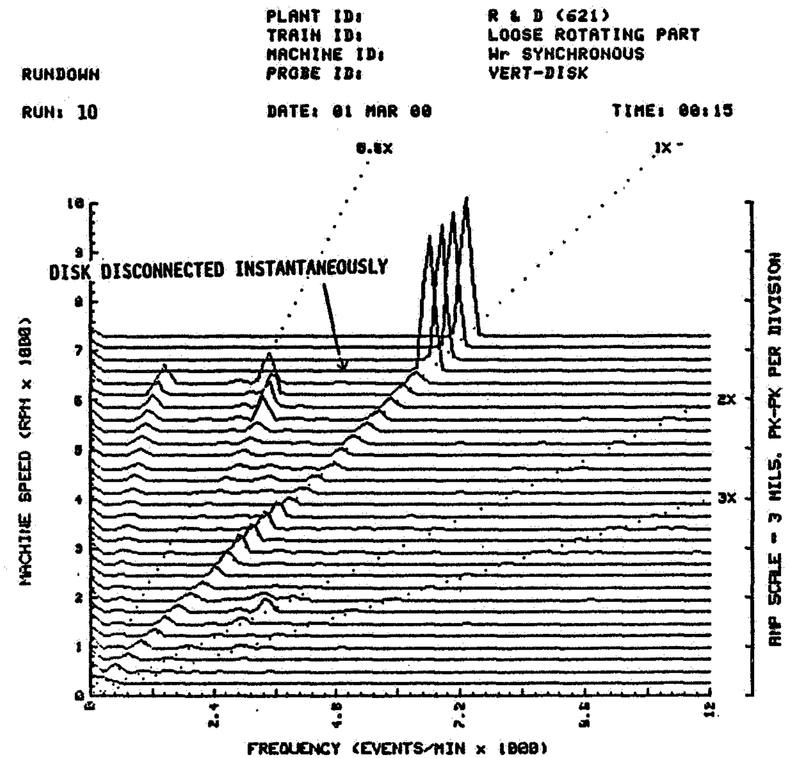

Figure 9. - Cascade spectrum of rotor response during shutdown. Two-blade disk disconnected from main rotor at rotative speed (6500 rpm). Frequencies of subsynchronous vibration caused by loose disk, ~1/4X and 3/5X. Latter meets first balance resonance frequency.

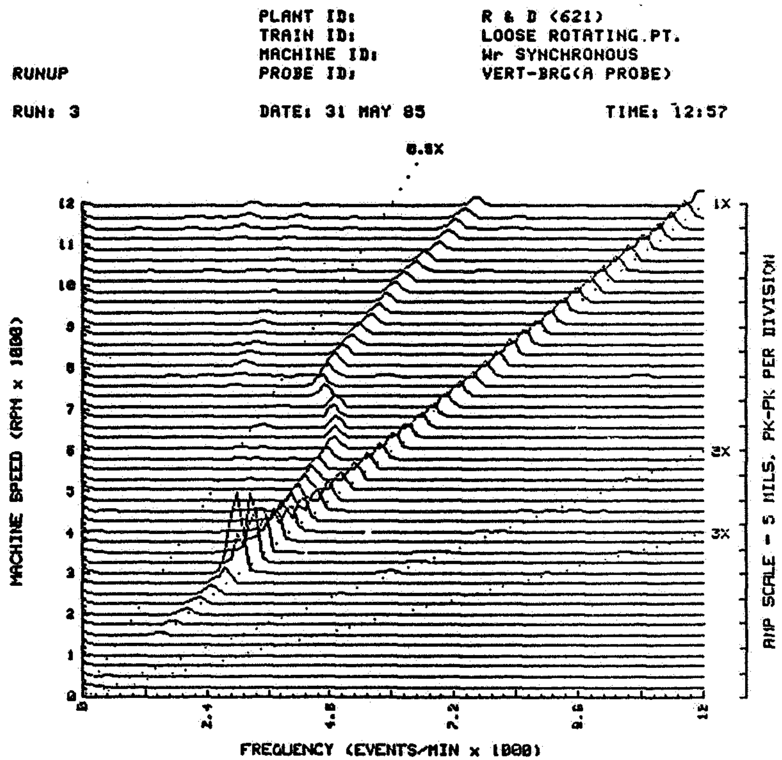

Figure 10. - Cascade spectrum for two-blade, loose-disk rotor startup response. Subsynchronous vibrations with variable frequency caused by loose part (probably due to variable friction/damping conditions at shaft/loose disk surface). Blades half size of those in previous tests (lower air drag).

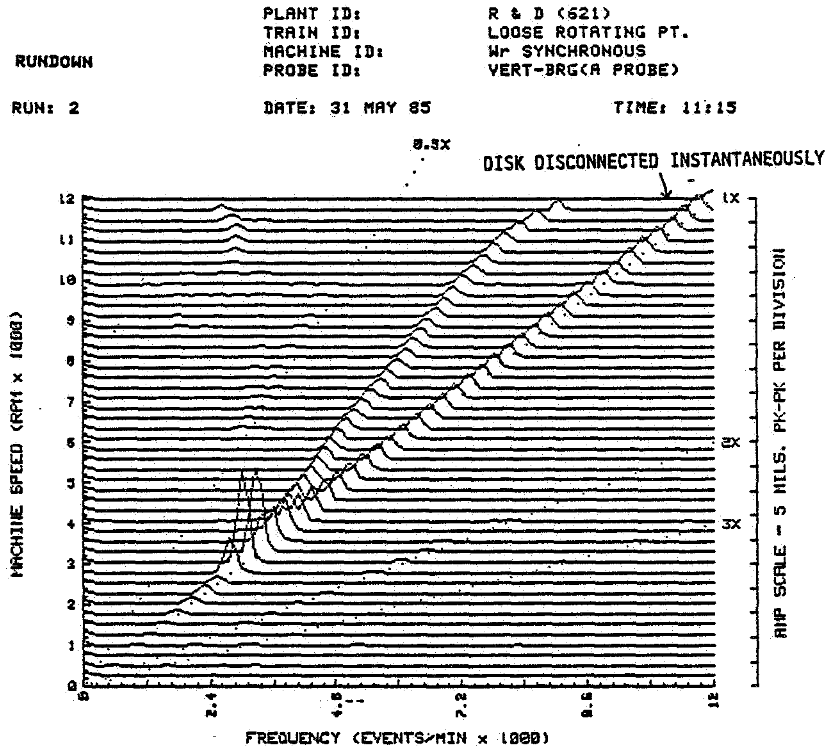

Figure 11. - Cascade spectrum of rotor response during shutdown. Two-blade disk disconnected from main rotor at rotative speed (11 900 rpm). Frequency of subsynchronous vibrations caused by loose disk first sharply, then slowly, decreasing. At first balance resonance speed subsynchronous vibrations disappear. Blades half size of those in previous tests (lower air drag).